CD-LINKS WP3 Global low-carbon development pathways

Protocol second round – June 2017

Contents

1 Introduction

Global low-carbon development pathways for the twenty-first century are developed in the global modelling exercise. These climate policy scenarios will take into account currently implemented and planned climate policies, and INDCs, which is input from WP2. As such, they will have an explicit representation of near-term policy trends. The scenarios are designed to allow for a re-estimation of emission reduction pathways towards long-term targets and the consequences of short-term decisions for long-term change.

2 Submission of results

Submission **deadline** for the third round of scenarios (Reference (NPi), INDCforever (INDCi), and the INDCi2030/NPi2020 1600,1000,400 scenarios) is **July 14th 2017.** This is the final date for submission of scenarios to the 1.5 degree special report. Model teams should let the WP leaders know which scenarios to include in this submission.

Teams have the possibility to also submit their preliminary scenarios **before June 15th.** This optional round will serve as additional check before the final submission.

Please use the updated CD-LINKS WP3 **model template**

Important changes in this submission:

- Submit scenarios with the extension _V3
- Reported climate policy costs have to be calculated using the NoPolicy baseline as a counterfactual scenario.
- Models that do not include the AFOLU and/or bunker CO_2 emission categories should use the exogenous emissions provided in this protocol (see section 9)
- Model teams should implement China's INDC target on CO_2 peaking (see description in section 6)
- International shipping emissions should only be reported globally (and not regionally).
- Model teams should aim for implementing at least 50% of the national policies as provided in the protocol in each of the sectors (Energy supply, Transportation, Industry, Residential, AFOLU, Economy wide). Note that this is an indicative goal. The focus should be on the highest impact policies. Especially Energy supply, transport and AFOLU are important as these result in the highest absolute reductions. Please indicate this and check the provided overview in the following Sharepoint document Implemented policies by IAMs

3 Brief description of scenarios

The WP3 Policy scenarios are briefly presented below:

Table 1 Scenarios in global modelling exercise

Policy dimension	Long-term CO_2 budget (2011-2100 cumulated; Gt CO_2)			
	None	1600	1000	400
NoPolicy	NoPolicy			
Reference (NPi) implemented policies: 1 (+2 to the extent represented)*	NPi	NPi2020_1600	NPi2020_1000	NPi 2020_400
Optional: ReferencePlanned (NPip) implemented & planned: 1+4 (+2+5 to the extent represented) *	NPip			
INDCforever (INDCi) implemented + INDCs: 1+3 (+2 to the extent represented) *	INDCi	INDC2030i_1600	INDC2030i_1000	INDC2030i_400
Optional: INDCFromPlanned (INDCip) implemented & planned + INDCs: 1+3+4 (+2+5 to the extent represented)*	INDCip		INDC2030ip_1000	INDC2030ip_400

* Numbers are presented in Table 2

The different types of policies considered in these scenarios for 2030 are shown in Table 2.

Table 2 2030 policy space for WP3 scenarios

Status of Policy	Implemented	Planned
National climate and energy policies	1	4
INDCs	N/A	3
National „other" policies GHG-relevant (incl. SD policies)	2	5

All scenarios in black in Table 1 are mandatory, while those in blue are optional.

The **Reference (NPi)** scenario describes energy, climate and economic projections for the period until 2030, based on currently implemented national policies relevant for achieving the internationally pledged INDC targets. The cut-off year for national policies is 2015. For each G20 country, a list of high impact policies is given representing currently implemented policies with high impact on GHG emissions. The

emission development after 2030 is based on the assumption that countries will pursue equivalent effort. This is represented by assuming constant relative CO_2eq emission reductions between NoPolicy and NPi between 2030 and 2100, which models should aim for as much as possible.

Modelling teams should strive to implement all policies. In case a policy measure is considered too specific for the model, teams may use proxy indicators, which are provided in Input IAM protocol.

The **ReferencePlanned (NPip)** scenario that includes both currently implemented and planned policies is optional (for a definition of currently implemented and planned policies, see chapter 5).

The **INDCforever (INDCi)** scenario assumes implementation of INDCs by 2030, but no further intensification of emission reduction commitments beyond the INDCs after 2030. The focus of our analysis for this scenario is the year 2030, which is the target year of most submitted INDCs. However, we assume that post-2030, countries will implement equivalent effort. For the INDCs, the same is done as for the Reference (NPi) scenario (so by assuming constant relative CO_2eq emission reductions between NoPolicy and INDCi between 2030 and 2100). It thus assumes a continuation of fragmented and highly diversified action and does not represent an intensification of efforts toward the achievement of the 1.5-2°C target as envisioned by the Paris Agreement, but rather the floor of ambition implied by the submitted INDCs. It thus represents a scenario of moderate, fragmented action in which the (conditional) commitments made in the INDCs are realized, but where the international community fails to ratchet-up 2030 targets and increase long-term ambition relative to the effort implied by the INDCs. This scenario will serve as a point of comparison for the 1.5°C and 2°C scenarios.

The **INDCforever_FromPlanned** (**INDCip**) scenario is optional and uses the ReferencePlanned (NPip) as a starting point, but incorporates the same INDC assumptions as has been specified for the INDCforever (INDCi) scenario (so by assuming constant relative CO_2eq emission reductions between NoPolicy and INDCip between 2030 and 2100).

The **INDC2030i** scenarios explore the feasibility of achieving 1.5-2°C-limits in a global cost-effective way, starting from INDC-based near-term pathways. The **NPi2020** scenario explores the feasibility of achieving the same long-term goals in the most cost-effective way, by starting from today's policies and allowing for overachieving of INDC targets. These pathways are composed of two distinct phases: in the first phase until 2020 (NPi2020) or 2030 (INDC2030i), they follow the developments of the Reference (NPi) or INDCforever (INDCi) scenario (i.e. NPi2020 achieves the currently implemented policies included in the Reference (NPi) scenario up till the year 2020, and INDC2030i achieves the INDC targets up till 2030). In the second phase starting from 2020 (NPi2020) or 2030 (INDCi2030), they assume stylized, comprehensive climate policies to limit cumulative 2011-2100 CO_2 budgets as indicated in Table 1, in line with long-term stabilization in the 1.5-2°C range. Teams are requested to try to run all scenarios, and to also report scenarios that are infeasible due to the tight emissions constraint.

4 General specifications for all scenarios

Although the modelling exercise focuses on all world regions (with often multiple countries aggregated to one region total), the main focus of the CD-LINKS project until 2030 (national and climate related policies), is on G20 countries (see Table 3). The European Union (EU) is treated as one region and the individual EU countries Germany, France, United Kingdom and Italy are not separately included.

Table 3 G20 Countries

Argentina	Canada	India	Mexico	South Africa	USA	Italy
Australia	China	Indonesia	Russia	South Korea	France	UK
Brazil	EU	Japan	Saudi Arabia	Turkey	Germany	

A summary of the general specifications is given below:

- Time horizon: 2005-2050, 5 year intervals (the analysis will focus on 2030 and 2005-2050, but models with longer time horizons are encouraged to submit data out to 2100)

- Regions: There are two sets of common comparison regions for the WP3 scenarios (similar as ADVANCE):
  - an indicative mapping with the 5 RCP regions and the 10 key regions as defined for the LIMITS project (AFRICA, CHINA+, EUROPE, INDIA+, LATIN_AM, MIDDLE_EAST, NORTH_AM, PAC_OECD, REF_ECON, REST_ASIA, REST_WORLD) (see also in [ADVANCE_WP6_Reference_Data_09122015_corrected.xlsx])
  - In addition, we request teams to report all G20 (see Table 3) separately and the following regions:
    - World, EU28, Middle_East and Africa (the two latter regions are as defined in the LIMITS database and in [ADVANCE_WP6_Reference_Data_09122015_corrected])
- Population projections according to SSP2
- GDP projections according to SSP2 or according to GECO+[1].

[1] https://ec.europa.eu/jrc/en/news/geco-road-paris-study-published

5 Detailed specifications of the reference scenarios (NPi/NPip)

The global modelling exercise includes two reference scenarios: **Reference (NPi)** and **ReferencePlanned (NPip)**. The first is mandatory, and the second is optional. Please focus on the mandatory scenarios first, and include the planned policies scenario only when the other scenarios are satisfactory. The starting point for both Reference scenarios is the list of high impact policies for G20 countries that was output of WP2.1.

Detailed specifications for the policy scenarios until 2030 can be found in:

- Input IAM protocol This file summarizes all information needed for the modelling exercise.

And additional background information can be found here:

- The climate policy database (http://climatepolicydatabase.org/index.php?title=CDlinks_policy_inventory)
- Spreadsheet 'CD-LINKS Policy data and settings' (accompanying spreadsheet with background information)

Climate policies on the high impact policy list can be policy targets from national policy documents (e.g. National Communication, strategy documents) or policy instruments (e.g. ETS, feed-in-tariff, renewable portfolio standard). In practice, policy instruments are often implemented to achieve national (often aspirational) policy targets. As it might be difficult to implement specific policy instruments in IAMs, we included aspirational policy targets as currently implemented policies, but only if they are backed by effective policy instruments. If the policy instrument ends before the policy target year, we assume continuation of the policy instrument, but only for around five years. This leads to the definition of implemented policy as either a policy adopted by the government (through legislation), or a non-binding target backed by effective policy instruments. Besides currently implemented policies, the high impact policy list also contains planned policies. Planned policies are often aspirational targets from strategic documents or policies in the pipeline to be adopted. The **Reference (NPi)** scenario includes currently implemented policies (labelled as implemented in protocol spreadsheet) and the **ReferencePlanned (NPip)** scenario includes both currently implemented and the most important planned policies.

The high impact policies were translated into generic impact indicators that can be implemented in integrated assessment models. These can be found in the sheet 'Protocol reference scenario' (see Figure 3), and numerically in 'Protocol reference (numerical)' This sheet also contains proxy indicators, which can be used in case the actual policy measures are too specific to be implemented in the model (the variable used is shown on the right side of the page!). The generic impact indicators for each G20 country are divided into the different sectors: economy-wide, electricity and heat, industry, buildings, transport, and agriculture and forestry. For each sector, they are further divided into 'GHG reduction', 'energy/renewables' and 'efficiency'. Some policies are defined in terms of reduction relative to baseline. In this case, there was not enough information to relate it to historical data and model teams need to assess whether the policy is already included in their baseline or not. Not all high impact policies could be

translated into generic impact indicators, especially appliance standards and building codes were difficult. So, model teams are encouraged to also implement these policies from the high impact policy list in their models, based on information provided by the Climate Policy Database.

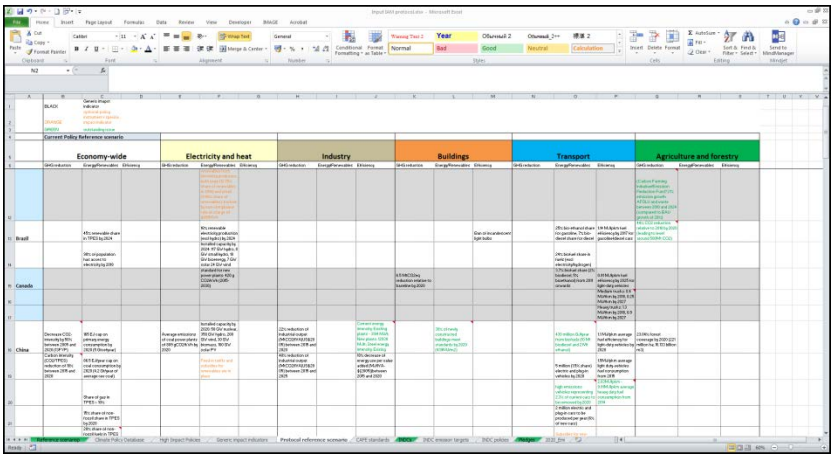

Figure 1 Generic impact indicator for currently implemented policies in Input IAM protocol

Some IAMs are not able to specify multiple policies that impact emissions in the same sector (e.g. economy-wide policy target plus a sector-specific policy target). If this is the case, policies should be implemented from bottom to top, so first (sub)-sector policies, and then if economy-wide targets are not met, more mitigation action should be implemented (through additional carbon taxes on a country level).

The time horizon is 2005-2050 and if possible out to 2100. The currently implemented policies are implemented out to 2030 and "equivalent effort" is assumed post-2030. The concept of 'equivalent effort' is not straightforward and therefore we provide guidelines in this protocol. Equivalent effort is seen as constant relative emission reductions with respect to the baseline.[2]

<u>Implementation of Policies to 2030:</u>

- Modelling teams are asked to implement at least the policies that are listed on the sheet 'Protocol reference scenario', but encouraged to also take into account other policies (especially policy instruments) that are on the 'high impact policies' list. Background information on specific assumptions used for the translation of high impact policies to generic impact indicators can be found in the spreadsheet 'CD-LINKS Policy data and settings'.
- On the sheet 'Protocol reference (numerical)' you find the same list as in 'protocol reference scenario', but listed row by row.
- Note the updates for some countries, based on national team reviews, in red: Brazil, China, India, Japan, Russian Federation, United States of America
- Note that there is a 'CAFE Standards' sheet that includes translations of fuel efficiencies for newly sold cars in MJ/pkm to gCO2/km and km/l.

[2] In case it is difficult to exactly follow this approach (i.e. for intertemporal optimization models), model team should aim for following it as much as possible, for instance by meeting the target in the year 2100.

- Biofuel shares are the percentage biofuels in gasoline and diesel in the transport sector, so excluding other fuels such as hydrogen and electricity
- No emissions constraints should be implemented for regions that do not have any specific policies listed on the 'high impact policies' and 'protocol reference scenario' lists.
- All renewable energy targets are assumed to apply to commercial energy (e.g. modern biomass) only, so non-commercial energy (e.g. traditional biomass) is excluded.
- Besides G20 country policies, the protocol includes non-G20 country policies, but only a few larger ones. These were taken from the ADVANCE project and have not been changed (see OTHER on sheet 'high impact policies'. This also accounts for non-G20 INDC emission targets (see INDC emission targets).
- In case policy measures cannot be implemented because they are too specific, teams should make use of the provided proxy indicators on the sheet 'Protocol reference (numerical)' (the variable used is shown on the right side of the page!). Energy system indicators have been derived from the IMAGE model. Land-use indicators have been derived from GLOBIOM and MAgPIE. Proxies have only been provided in case the policy measure has been successfully implemented in IMAGE/GLOBIOM/MAgPIE and if the policy measure can potentially be too specific for other models. Usable proxy indicators are indicated by green shaded cells. Energy system indicators include the relevant energy use (primary/secondary/final) and energy intensity change in NoPolicy and NPi. Land-use indicators include the change in CO_2 emissions.
- Compliance with Copenhagen pledges. The scenario analysis does not aim to specifically implement Copenhagen pledges.

<u>Implementation of Policies Post-2030:</u>

- Assume constant relative CO_2 equivalent (all GHG without LULUCF) emission reductions compared to the NoPolicy baseline, i.e. for 2030-2100 implement relative emission reductions equal to those relative emissions reductions in 2030 for all regions. In case it is difficult to exactly follow this approach (i.e. for intertemporal optimization models), model teams should aim for following it as much as possible, for instance by meeting the same relative reduction target in the year 2100.
- For LULUCF emissions, model teams may decide themselves on how to best represent "equivalent effort" after 2030.
- Models that are missing the emission categories CO_2 AFOLU or CO_2 international shipping, should make use of the provided exogenous global emissions for these categories (see section 9), by including the cumulative emissions in the 2011-2050 and 2011-2100 emission budgets and if possible in the yearly global CO_2 emissions.

6 Detailed specifications of the INDCforever (INDCi) scenario

The starting point for the **INDCforever (INDCi)** scenario is the Reference (NPi) scenario. If you have also modelled a ReferencePlanned (NPip) scenario, you are asked to create two INDCforever scenarios: **INDCforever (INDCi)** and **INDCforeverFromPlanned (INDCip)**. We will only describe the INDCforever (INDCi) scenario in this protocol. The INDC targets in the INDCforeveverFromPlanned are the same as the INDCforever (INDCi) targets, but the INDCforeverFromPlanned only starts from a different Reference (NPi) scenario. INDC emission reduction targets are given in the 'INDC emission targets' and 'Protocol INDCs (numerical)' sheets in Input IAM protocol.

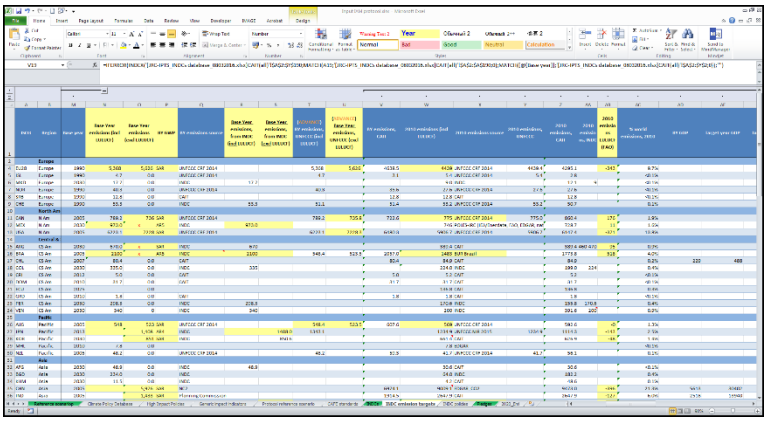

Figure 2 INDC emission targets from the input IAM protocol

The **INDCforever (INDCi)** scenario should include the conditional INDC targets. In these worksheets, all necessary information is provided to enable model implementation of INDCs.

The INDC targets are provided under the sheet 'INDC emission targets'. The GHG emission levels are based on information supplied by countries in the INDCs, national communications, or UNFCCC CRF files. Additional information on national emissions and GDP can be found in the spreadsheet 'CD-LINKS Policy data and settings'. For the INDC emission reductions as fraction of base year 2005 or 2010, use historical data from PRIMAP[3].

[3] http://pmd.gfz-potsdam.de/pik/showshort.php?id=escidoc:1504004

Implementation of INDCs to 2030:

- Base year data: Teams are requested to use the PRIMAP and FAOSTAT data and First results and remarks in Check implementation of policies and NDCs to make the historical comparison, explain large differences and fill out the questionnaire (only use the GHG emission sheets).
- Model teams should implement the relative reductions, unless this leads to large deviations from the absolute emission targets (try to stay within maximum deviations: 5% worldwide, 10% regional – energy/industry and 20% in regional - land use).
- For convenience and consistency across all teams, all INDC targets have been expressed in relation to 2010 emissions in columns AU and AV and in relation to 2005 emissions in columns AS and AT of 'INDC emission targets'. Note that these are only valid if your model is calibrated to 2010 (or 2005) historical emissions. The emission target relative to 2010 is not available for Ecuador, Philippines, Algeria and Central African Republic, because their BAU (point of reference for the INDC) is not provided in the respective document. However, teams that may have a BAU scenario for those individual countries are welcome to use it.
- LULUCF targets: It is important to correctly take into account the LULUCF sector when implementing INDC targets in IAM models. There are two ways that countries can specify the use of LULUCF as part of their INDC emission reduction target: 1) (full accounting) those that specify emission reduction targets including LULUCF (also in base year) and 2) (accounting rules) those that specify emission reduction targets excluding LULUCF and account for LULUCF credits[4]. For countries with large LULUCF emissions, the INDC emission levels are given for both including and excluding LULUCF, based on Grassi and Dentener (2015) and (Den Elzen, 2015) or national communications. As most models do not include the LULUCF sector, it is recommended to implement the INDC target excluding LULUCF. For this purpose the worksheet 'INDC emission targets' includes six columns: '(CD-LINKS) Emissions "conditional" vs 2005 (incl LULUCF)' (column AS), '(CD-LINKS) Emissions "conditional" vs 2005 (excl LULUCF)' (column AT), '(CD-LINKS) Emissions "conditional" vs 2010 (incl LULUCF)2' (column AU), '(CD-LINKS) Emissions "conditional" vs 2010 (excl LULUCF)2 ' (column AV), '(CD-LINKS) Emissions "conditional" at target year (incl LULUCF)' (column AW), and '(CD-LINKS) Emissions "conditional" at target year (excl LULUCF)' (column AX), showing the impact of LULUCF emissions. All numbers are also provided in a long list in sheet 'Protocol INDCs (numerical)'.
- For countries with GHG intensity targets and additional INDC targets (China, India), teams should implement all targets in their model, aiming to meet each of the individual targets. China's INDC includes *an intention to peak CO2 emissions around 2030, making best efforts to peak earlier*, to reduce the carbon intensity of GDP by 60-65 per cent from 2005 levels by 2030, to increase the share of non-fossil fuels in primary energy consumption to around 20 per cent by 2030. **If unabated emissions would keep rising (such as in the INDCi scenario), models should keep China's CO_2 emissions constant after 2030.**

  For India, the NDC includes to reduce the emissions intensity of its GDP by 33 to 35 per cent by 2030 from 2005 level; and conditional, to achieve about 40 per cent cumulative electric power installed capacity from non-fossil fuel based energy resources by 2030 with the help of transfer of technology and low cost international finance including from Green Climate Fund (GCF). Note that

[4] See section 4.3.3. from http://www.metoffice.gov.uk/media/pdf/r/3/AVOID_WS2_D1_29_LULUCF_16-01-12.pdf

implementation of the additional INDC targets into IAMs is very important, as several literature studies conclude that these additional targets are more stringent than the GHG emission (intensity) targets. INDCs that include emission intensity targets have been quantified for both GECO and WP6 Reference GDP levels (column AS/AT in 'INDC emission targets'). But make sure to implement the additional renewable/non-fossil and LULUCF targets.

- INDCs in general consist of GHG emission reduction targets, but are sometimes accompanied with sector-level targets. This is the case for two G20 countries: China and India. The GHG emission reduction targets are specified in the worksheet 'INDC emission targets', while the additional sector-level policies/targets can be found in the worksheet 'INDC policies'.
- Accounting method non-fossil target China: teams should use the "substitution" accounting method (Moomaw et al., 2011) for the implementation of the Chinese TPES target. This should be implemented not only for 2030 but for the entire period. Teams are advised to use static coefficients, i.e. for electricity 38% (applied to non-combustible, non-fossil electricity production, e.g. modern biofuels, nuclear, solar PV, CSP, wind onshore/offshore, hydro) and for heat 85%. Thus teams can calculate TPES as
    - TPES_substitution_metod = TPES_direct_equivalent_method / efficiency_coal_fired_power_plant.
- Regional Aggregation or disaggregation: Overall, data (absolute levels and growth rates) has been provided for 39 separate regions to enable teams to adjust the data to their model regions in an accurate manner. See the ADVANCE spreadsheet JRC-IPTS_INDCs database_08032016.xlsx for GHG emissions excluding LULUCF and 'CD-LINKS Policy data and settings' for LULUCF emissions from FAOSTAT.
- Aggregation/disaggregation of regions for the implementation of emission reduction targets should be based on historical 2010 emission levels.
- Aggregation: emission reduction targets have been provided for 63 countries in the "INDC emission targets" sheet. See Section 8 for a detailed explanation of the aggregation method. Teams are advised to base their implementation on the emissions indexed to 2010 as provided in column AU/AV as described above. But only if the IAM is harmonized to 2010 emissions as absolute emission levels in 2030 are important for long-term mitigation scenarios based on carbon budgets. To aggregate country-level INDC emission targets to their model-specific macro-regions, teams should calculate the combined emissions index (emission multiplier from 2010 to 2030) as

$$\overline{EIndex}^{INDC} = \frac{\overline{E}^{INDC}_{2030}}{\overline{E}_{2010}} = \frac{1}{\overline{E}_{2010}}\left(\sum_{i\ w/\ target} E_{i,2010}\ EIndex_i^{INDC} + \sum_{i\ w/o\ target} E_{i,2010}\ \overline{EIndex}^{BAU}_{2030}\right)$$

where the sums run over countries *i* with (*i w/target*) and without (*i w/o target*) an INDC emissions target, and $\overline{EI}^{BAU}_{2030}$ refers to the emissions index of the macro-region observed in a NoPolicy baseline or in WP3 Reference (NPi) scenario.

- No emissions constraints should be implemented for regions that do not have any specific target for emissions.
- If the carbon value that corresponds to the prescribed Reference (NPi) emission reduction of low-income and lower-middle income[5] countries exceeds 25% of the EU carbon price, then the emission reduction constraint should be relaxed so as to lower the carbon value to the prescribed level of 25% of the EU price.
- Compliance with Copenhagen pledges. The scenario analysis does not aim to specifically implement Copenhagen pledges.

Implementation of INDCs 2030-2050:

As described above, the INDCforever (INDCi) scenario is a high ambition scenario of fragmented mitigation action. So for the period beyond 2030, teams are requested to implement constant relative CO_2 equivalent (all GHG without LULUCF) emission reductions compared to the NoPolicy baseline, i.e. for 2030-2100 implement relative emission reductions equal to those relative emissions reductions in 2030 for all regions. In case it is difficult to exactly follow this approach (i.e. for intertemporal optimization models), model teams should aim for following it as much as possible, for instance by meeting the same relative reduction target in the year 2100.

For LULUCF emissions, model teams may decide themselves on how to best represent "equivalent effort" after 2030.

[5]According to the World Bank for the current 2016 fiscal year, low-income economies are defined as those with a GNI per capita, calculated using the *World Bank Atlas* method, of $1,045 or less in 2014; middle-income economies are those with a GNI per capita of more than $1,045 but less than $12,736; high-income economies are those with a GNI per capita of $12,736 or more. Lower-middle-income and upper-middle-income economies are separated at a GNI per capita of $4,125. ADVANCE WP6 does not use GNI but GDP levels, hence teams can identify low-income and lower-middle income countries in the relevant table of World Bank and assume no change of this classification until 2050.

7 Detailed specifications of the INDCi2030 and NPi2020 long-term carbon budget scenarios

The CO_2 budgets apply to the 90-year period starting with the beginning of 2011 and ending with the end of 2100, including all CO_2 emissions (Energy, other industrial processes and AFOLU).

NPI2020: keep results the same as in Reference (NPi) up to 2020.
INDCI2030: keep results the same as INDCforever up to 2030.

Post-2020 or post-2030 assume stylized, comprehensive climate policies (CO_2 prices equalized across regions and sectors) limiting cumulative 2011-2100 CO_2 budgets as indicated (1600, 1000, 400 Gt CO_2 cumulative 2011-2100). The same CO_2-price shall be applied to non-CO_2 greenhouse gases to ensure comparable mitigation efforts across gases.

For models that require a trajectory of CO_2 emissions for the post-2030 period, the file "ADVANCE-INDC-CO2-long-term-trajectories.xlsx" provides indicative CO_2 emissions (both total and for Fossil Fuels & Industry, FFI) in 5 year time step resolution from REMIND. If you use these trajectories, please adjust the post-2030 trajectories for higher or lower CO_2 emissions in the 2011-2030 period in your model, and/or if your model time step representation is not identical to that of REMIND (in REMIND, "2010" represents the years 2008-2012), so that the 2011-2100 CO_2 total budget matches the required values (400, 1000 or 1600 Gt). For REMIND, the scenario INDC2030_400 is not feasible, so no indicative trajectory can be provided.

8 Aggregation of G20 policy information into native model regions

Aggregation into model regions

The protocol specifies policy targets for G20 countries. In case these G20 countries are part of a larger region, aggregation into model regions is necessary. Please do not share this methodology outside CD-LINKS as this is considered for publishing. The guideline (see appendix for details) is:

- For GHG emission reduction targets (INDCs), use the ADVANCE approach (see Chapter 6)
- For other policy targets that sometimes are specified at different levels (e.g. economy-wide and sector-specific), choose the target type from the dominant country within the region. If there is an economy-wide target, this is preferred over sector targets, as the latter can be more easily translated into the first. The aggregation might be necessary for different types of policy targets:
    - Different types of renewable energy targets (e.g. TPES, electricity production, final energy, incl./excl. nuclear or hydro)
    - Different types of intensity targets (TPES/GDP, industry intensity, buildings intensity)
- Translate all country targets into the dominant country's target type
- For countries without a target, assume the target is equal to the region baseline (NoPolicy)
- Aggregate these translated country targets using (example is renewable share of total primary energy production):

$$share_{R;TY} = \sum_{c=1}^{N} \frac{Energy_{c;RY}}{Energy_{R;RY}} * Tshr_{iso;TY}$$

$$= \frac{1}{Energy_{R;RY}} \left(\sum_{c\ with\ target} Energy_{c;RY} * Tshr_{iso;TY} + \sum_{c\ without\ target} Energy_{c;RY} * BAU\_shr_{TY} \right)$$

Where:

- R = region
- C = country
- TY = target year
- RY = reference year (last year of available historical data to split region into countries)
- $Tshr_{iso;TY}$ is the (recalculated) national target share in the target year (*TY*) and if necessary, translated from its original type to the dominant country's target type.
- BAU_shr_{TY} is the model baseline (NoPolicy) share in the target year (*TY*)

An example of translation of a country target into the dominant country's target type: suppose we have a Latin America region, and Argentina and Brazil have renewable energy targets. Argentina has a hydro capacity target and Brazil has a renewable TPES target. Then the dominant target would be the REN TPES target, as Brazil is the dominant country within the region. Then the Argentina hydro target should be translated into its impact on TPES. And the two REN TPES targets should be aggregated (also including other countries within the region) using the above formula.

9 Exogenous global AFOLU and international shipping CO_2 emissions

Table 4 and 5 below provide exogenous data for models that do not include CO_2 AFOLU and/or international shipping emissions. This data should in such case be used to calculate long-term CO_2 budgets for all the sectors that *are* included in the model or, if possible, as exogenous emission category data. Yearly global total values are provided, as well as cumulative totals for the periods 2011-2050 and 2011-2100. Data has been based on (V2) scenario output of the IMAGE and MESSAGE-GLOBIOM models (average of both models, AFOLU emissions harmonized with historical FAO data, international shipping emissions harmonized with EDGAR) for all scenarios.

Table 4 Global CO_2 AFOLU emissions (in Gt CO_2)

	NoPolicy	NPi	NPip	INDCi	INDCip	INDC 2030i_1600	NPi 2020_1600	INDC 2030i_1000	INDC 2030ip_1000	NPi 2020_1000	NPi 2020_400
2010	2615	2615	2615	2615	2615	2615	2615	2615	2615	2615	2615
2015	2885	2689	2689	2689	2689	2689	2689	2740	2739	2740	2692
2020	3685	2949	2956	2949	2956	2949	2949	2883	2898	2883	2645
2025	3847	3067	3105	2912	2973	2912	2337	2738	2767	2084	1624
2030	4249	3148	3166	2817	2841	2822	1534	2403	2478	980	344
2035	4650	3639	3628	3256	3314	2727	1750	2254	2292	1049	-123
2040	4571	3164	3161	2972	2933	1587	1181	1118	1130	676	-542
2045	4349	2418	2407	2242	2183	919	810	1007	955	1110	-304
2050	3808	2052	2024	1835	1773	1252	636	1232	1194	300	500
2060	1521	831	699	310	277	-1095	-1410	-1425	-1432	-1924	-2054
2070	806	151	82	-138	-147	-1427	-1687	-1689	-1662	-2223	-2024
2080	471	-129	-173	-273	-312	-1666	-1751	-2427	-2451	-2541	-2190
2090	-200	-745	-783	-881	-872	-832	-2233	-2383	-2418	-2268	-2062
2100	-588	-1194	-1259	-1262	-1296	-1799	-2098	-2106	-2154	-2324	-2228
Cumulative budget											
2011-2050	157	117	117	110	110	93	74	85	86	65	39
2011-2100	199	122	119	103	102	40	-4	2	1	-35	-52

Table 5 Global CO_2 international shipping emissions (in Gt CO_2)

	NoPolicy	NPi	NPip	INDCi	INDCip	INDC 2030i_1600	NPi 2020_1600	INDC 2030i_1000	INDC 2030ip_1000	NPi 2020_1000	NPi 2020_400
2010	626	626	626	626	626	626	626	626	626	626	626
2015	679	674	675	674	674	674	674	674	674	674	674
2020	715	702	701	702	701	702	702	702	701	701	701
2025	730	715	708	705	701	705	694	705	701	691	612
2030	742	729	717	705	700	708	665	707	704	632	508
2035	739	723	712	701	697	626	587	500	500	499	485
2040	732	715	706	695	692	488	550	477	476	475	466
2045	731	707	699	691	688	471	555	444	443	461	443
2050	728	698	693	685	680	531	565	420	420	450	419
2060	741	692	691	681	679	461	531	365	366	441	339
2070	752	708	705	703	700	453	469	246	246	416	234
2080	759	727	722	714	710	430	449	185	185	335	185
2090	760	736	730	722	718	343	400	153	153	227	159
2100	758	724	718	713	711	225	271	145	145	168	152
Cumulative budget											
2011-2050	29	28	28	28	28	25	25	24	24	23	22
2011-2100	66	64	63	63	63	45	48	36	36	41	34

LITERATURE

Den Elzen MF, H., Admiraal, A., Hohne, N., Korosua, A., Roelfsema, M., Soest, H., Wouters, K., Day, T., Hagemann, M., Hof, A., Mosnier, A. (2015) Enhanced policy scenarios for major emitting countries. Analaysis of current and planned climate policies, and selected enhanced mitigation measures. PBL.

Elzen D, Admiraal A, Roelfsema M, Soest H, Hof AF, Forsell N (2016) Contribution of G20 countries to the global impact of the Paris Agreement climate proposals. Climatic Change 137:655-665.

Grassi G, Dentener F (2015) Quantifying the contribution of the land use sector to the Paris Climate Agreement, https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/quantifying-contribution-land-use-sector-paris-climate-agreement. EC Joint Research Centre. Institute for Environment and Sustainability.

Kitous A, Keramidas K, Vandyck T, Saveyn B (2016) GECO 2016. Global energy and climate outlook. Road from Paris. Impact of climate policies on global energy markets in the context of the UNFCCC Paris Agreement. in JRC (ed.) JRC Science for policy report. Joint Research Centre.

Moomaw W, Burgherr G, Heath G, Lenzen M, Nyboer J, Verbruggen A (2011) Annex II: Methodology. In IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation. Intergovernmental Panel on Climate Change.